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ASSESSMENT OF ENVIRONMENTAL TOBACCO SMOKE AND RESPIRABLE SUSPENDED PARTICLE EXPOSURES FOR NONSMOKERS IN HONG KONG USING PERSONAL MONITORING

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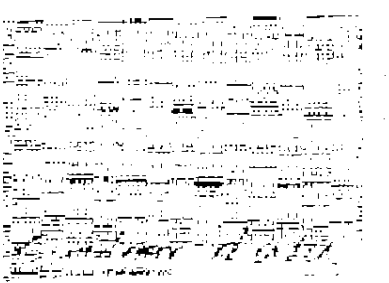
One hundred and ninety-four randomly selected nonsmoking subjects collected air samples in their breathing zone by wearing personal monitors for 24 h. The study was centered in Hong Kong, and comprised housewives in one group, primarily for assessing exposures in the home, and office workers in a second group to assess the contribution of the workplace to overall exposure. Samples collected were analysed for respirable suspended particles (RSP), nicotine, 3-ethenylpyridine, and environmental tobacco smoke (ETS) particles using ultraviolet absorbance (UVPM), fluorescence (FPM), and solanesol measurements (SolPM). Saliva cotinine analyses were also undertaken to confirm the nonsmoking status of the subjects and to investigate their correlation with ETS exposure measurements. Approximately 6% of the subjects in Hong Kong misclassified their nonsmoking status. Median time-weighted average (TWA) RSP concentrations varied from 43 to 54 μg m^{-3} with no significant differences detected between any of the groups investigated. Office workers who lived and worked with smokers were exposed to 2.6 μg m^{-3} ETS particles (SolPM) and 0.44 μg m^{-3} nicotine, based on median TWA concentrations. Median concentrations of ETS particles and nicotine were below the limits of quantification for housewives living with smokers and were not significantly different from those for housewives living with nonsmokers. It would therefore be unreliable in Hong Kong to use a smoking spouse as a marker for assessing health risks related to ETS exposure. The office workers in this study were significantly more exposed to ETS than housewives from either smoking or nonsmoking homes, and the workplace was estimated to contribute over 33% of the annual exposure to ETS particles and nicotine. Exposure estimates suggest that the most highly exposed office workers in this study receive between 11 and 50 cigarette equivalents per year, based upon upper decile levels for ETS particles and nicotine, respectively. ©1998 Elsevier Science Ltd



INTRODUCTION

Hong Kong was the first Asian city studied by these authors for air quality, following European investigations in Stockholm (Phillips et al. 1996), Barcelona (Phillips et al. 1997a), Turin (Phillips et al. 1997b), Paris (Phillips et al. 1998a), Bremen (Phillips et al. 1998b), Lisbon (Phillips et al. 1998c), Basel and Prague (Phillips et al. 1998d). Hong Kong, with a

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population of approximately 6 million, is now part of the Peoples Republic of China, but was a British colonial territory at the time of the study. Air quality is of particular concern in this city where environmental pressures are exacerbated by the world's highest residential density of nearly 1000 people per ha.

The Environmental Protection Department (EPD) is Hong Kong's agency responsible for the enforcement of environmental legislation and planning against pollution. For respirable suspended particles (RSP), the EPD has set an annual objective of 55 $\mu g\ m^{-3}$ and 80 $\mu g\ m^{-3}$ for total suspended particles (TSP). In its annual review, the Department indicated that the majority of RSP in urban areas are derived from combustion sources, especially diesel vehicle exhausts (Gervat 1995). At the time of this study, the local media were suggesting the removal of diesel vehicles from the streets of Hong Kong. A recent study on more than 300 vehicles in the United States (Wang et al. 1997) showed a significant reduction in particulate emissions (PM_{10}) from engines running on alternative fuels.

Personal air monitoring was chosen for this study in preference to static or ambient measurements to more accurately represent personal exposures to selected pollutants. The study involved subjects monitoring the air in their breathing zone over 24-h periods in Hong Kong during January/February 1996. Environmental tobacco smoke (ETS) particles were estimated using ultraviolet absorbing particulate matter (UVPM), fluorescing particulate matter (FPM), and solanesol related particulate matter (SolPM). Vapour phase ETS exposures were also assessed by simultaneous measurement of nicotine and 3-ethenylpyridine (3-EP) concentrations. In order to evaluate exposures to ETS and RSP, households and workplaces were classified as smoking or nonsmoking. Subjects also provided saliva samples for cotinine analysis and self-reported activities using diaries and questionnaires. Similar methodologies were used in other recent studies (Sterling et al. 1996; Jenkins et al. 1996; Baek et al. 1997).

The study set out to assess the exposure of housewives and office workers to RSP and ETS particles by obtaining accurate measurements of air concentrations. The information collated here should provide some meaningful data to allow informed and objective debate on issues related to ETS exposure and exposures to RSP overall. The main objectives of this study were:

1) to recruit subjects at random from a database representative of the population of Hong Kong into six separate lifestyle "Cells";
2) to determine the range and degree of personal exposure of these Cells of selected subjects to RSP and ETS constituents by means of personal air sampling over a 24-h period; and
3) to assess the contribution of the workplace to overall exposure of ETS and RSP.

METHODS

Recruitment of subjects

Recruitment was performed by Survey Research Hongkong Ltd. (SRH), a leading Asian marketing company, who possessed one of the most complete personal databases in the region. A random sample population was selected from their database to be compliant with the following criteria:
1) all subjects to be nonsmokers living within 15 km of Hong Kong City centre;
2) equal proportions from three age groups 20-34, 35-49, and 50-64;
3) subjects' lifestyles to closely resemble the population within 15 km of the city centre specifically based on the Cells listed below; and
4) subjects to be distributed between six "Cells" as indicated in Table 1, Cells 3-6 being targeted at office workers.

Subjects were recruited by telephone using numbers selected at random from a database of potential volunteers, who were screened to confirm their eligibility to participate in the study. Suitable volunteers were given an appointment to attend an information/training session organised at the offices of SRH on Hong Kong Island.

In order to assign subjects into Cells, as depicted in Table 1, their households were classified as "smoking" if a smoker of cigarettes, pipes, or cigars was resident and also normally smoked within communal areas of the household. The smoking status of a workplace was defined by the absence/presence of smoking coworkers within 30 m of the subject's workstation. These definitions were chosen to best represent 'real world' situations and for consistency across the different cities under study, since attitudes of residents vary considerably from country to country. The regulations governing air quality in the workplace were also different in each country at the time the study was undertaken.

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Table 1. Cell categorisation by home and workplace status (Hong Kong).

Cell	Study type	Smoking status		Planned number
		Household	Workplace	
1	Single monitor	Smoking	-	55
2	Single monitor	Nonsmoking	-	40
3	Dual monitor	Smoking	Smoking	45
4	Dual monitor	Smoking	Nonsmoking	30
5	Dual monitor	Nonsmoking	Smoking	40
6	Dual monitor	Nonsmoking	Nonsmoking	30

The monitoring session

Subjects were required to wear a personal monitor, designed to collect particulate and vapour phase components present in the air close to the subject's breathing zone (Ogden et al. 1996). The RSP and ETS particles were collected onto a Fluoropore membrane filter. Nicotine and 3-EP were adsorbed onto XAD-4 resin beads. The personal monitoring methodology was described in detail elsewhere (Phillips et al. 1996) and consisted briefly of the following:

1) Initial visit to the study centre: On arrival, the subjects were shown an instructional video, either in English or dubbed into Cantonese, explaining the objectives of the air quality survey, and were given further instructions regarding use of the equipment and how to complete the documentation by locally recruited interpreters. The subjects were issued the appropriate language questionnaires and diaries for recording exposures and observations over the 24-h collection period, and were supervised during completion of a "first visit" questionnaire. To avoid misinterpretation and possible errors in translation, all questionnaires and diaries were designed for either numeric or tick-box answers. Nonworking subjects recruited for participation in Cells 1 and 2 were provided with a single personal monitor for use over the collection period (single monitor study). Working subjects recruited for participation in Cells 3 to 6 were provided with two personal monitors for use over the same period (dual monitor study). All subjects were required to provide a saliva sample prior to the monitoring period (pre-sample).

2) Final visit to the study centre: Following completion of the 24-h monitoring period, the subjects returned their personal monitors and associated documentation to the study centre. The subjects also provided a second saliva sample (post-sample) and completed a "last visit" questionnaire.

ANALYTICAL PROCEDURES

All analytical procedures were validated and were fully described previously by these authors (Phillips et al. 1996). In this study, the following analytes were determined:

1) RSP - using a gravimetric procedure (Ogden et al. 1990);

2) Saliva cotinine - using a radioimmunoassay procedure (Van Vunakis et al. 1987; Davis and Stiles 1993);

3) Nicotine and 3-EP - using a capillary gas chromatography (GC) procedure with nitrogen specific detection (Ogden et al. 1989); and

4) Estimation of ETS particles (3 procedures) - using high performance liquid chromatography (HPLC) procedures to determine the UVPM, FPM, or SolPM content of methanolic filter extracts (Ogden et al. 1990; Phillips et al. 1996). The factors used in this study to convert instrument responses into an equivalent concentration of ETS particles were 38 (SolPM), 47 (FPM), and 8.4 (UVPM) as determined by Nelson et al. (1997).

The analytical limits of quantification (LOQ) for these analyses are presented in Table 2, together with the proportion of data below the LOQ. In order to calculate summary statistics, any data below the analytical LOQ were assigned a value of ½LOQ prior to the calculation of exposure concentration using the appropriate air sampling volume. The LOQs expressed as air concentrations in Table 2 are therefore only an approximation, as they varied for each sample dependent upon the sampling pump flow rate and monitoring time.

SUBJECT SELECTION

Of the 207 subjects initially recruited for the study, 2 were excluded after having admitted to being smokers during their initial visit to the study centre. A further 11 subjects were excluded because their saliva

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Table 2. LOQ for the analytical methods (Hong Kong).

Measurement*	Analytical LOQ	LOQ expressed as an air concentration according to sampling time (μg m^{-3})** 24 h	14.9 h[1]	9.0 h[2]	Proportion of data below the LOQ
RSP	28.3 μg/filter	11	18	31	13%
UVPM	1.26 μg/filter	0.51	0.82	1.4	5%
FPM	0.30 μg/filter	0.12	0.20	0.32	2%
SolPM	0.57 μg/filter	0.23	0.37	0.61	53%
Nicotine	0.1 μg/tube	0.09	0.14	0.23	64%
3-EP	0.1 μg/tube	0.09	0.14	0.23	70%
Saliva cotinine	1.0 ng mL^{-1}	--	--	--	65%

* RSP: Respirable suspended particles; UVPM: ETS particles estimated by ultraviolet absorption; FPM: ETS particles estimated by fluorescence; SolPM: ETS particles estimated by solanesol content.
** A flow rate of 1.72 L min^{-1} through the Fluoropore filter was assumed in the LOQ calculation for RSP, UVPM, FPM, and SolPM. The LOQ calculation for nicotine and 3-EP assumed a flow rate of 0.8 L min^{-1} through the XAD-4 tube.
[1] Mean time spent outside the workplace for working subjects in Hong Kong.
[2] Mean time spent at work for working subjects in Hong Kong.

Table 3. Age and sex distribution for study subjects (Hong Kong).

Subject group	Sex		Age range			Overall total
	Males	Females	20-34	35-49	50-64	
Cell 1		35	2	10	23	35
Cell 2		35	4	8	23	35
Cell 3	10	11	12	4	5	21
Cell 4	9	20	23	3	3	29
Cell 5	20	11	14	9	8	31
Cell 6	25	18	26	10	7	43
Single monitor total		70	6	18	46	70
Dual monitor total	64	60	75	26	23	124
Overall total	64	130	81	44	69	194

Cell 1: smoking household; Cell 2: nonsmoking household; Cell 3: smoking household/smoking workplace; Cell 4: smoking household/nonsmoking workplace; Cell 5: nonsmoking household/smoking workplace; Cell 6: nonsmoking household /nonsmoking workplace.

cotinine levels were above the selected threshold (25 ng mL^{-1}) for nonsmokers.

The age and sex distributions of the remaining 194 subjects who successfully completed the study are presented in Table 3. The sex distribution was close to the planned 50% per sex for office workers in the dual monitor study (52% male, 48% female). The age distribution for office workers showed a considerable variation from the planned 33% for each age group, with 60% of the recruits in the youngest (20-34 y) age group. Housewives in the single monitor study showed the opposite bias in age range distribution with nearly two-thirds of the recruits being from the oldest (50-64 y) age group. The dual monitor study participants were also questioned about their occupation on the last visit questionnaire. Subjects were restricted to a choice of 12 occupations from which to select and provide their answers as summarised in Table 4.

During recruitment, it was apparent that smoking was not widespread in indoor environments, and difficulties were encountered in recruiting subjects from smoking households and, in particular, smoking workplaces. Recruitment of the planned number of subjects into certain Cells thus proved unachievable.

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Table 4. Occupations of recruited working subjects (Hong Kong).

Occupation	Number of responses
Administrative/secretarial	39
Building/construction	1
Education	7
Engineering	11
Government agency (civil service)	8
Legal/financial (e.g., solicitor, banker)	8
Hotel/restaurant/leisure industry	2
Medical (e.g., doctor, nurse)	1
Transportation/haulage	4
Wholesale/retail (e.g., shop assistant)	4
Science/computing	8
Supply industry	0
Other	31
Total	124

WEATHER AND POLLUTANT INFORMATION

Information on the weather conditions and the levels of certain airborne pollutants was compiled by CES (Asia) Ltd. based upon information obtained from the relevant local government offices in Hong Kong during the period 10 January 1996 to 7 February 1996.

Weather conditions were recorded at the Royal Observatory station (Tsim Sha Tsui) in Kowloon, close to the main crossing point to Hong Kong Island at Victoria Harbour. The study period was during the dry season in Hong Kong, with rainfall (maximum 3 mm) observed on only 4 d, and a recorded maximum and minimum relative humidity of 94% and 58%, respectively. The temperatures, reported as hourly means, ranged from 12.1 to 24.1°C and the wind speeds varied between 2.0 and 2.7 km h^{-1}.

Airborne pollutant data recorded during the study period were obtained from fixed site monitoring stations operated by the Hong Kong EPD. The TSP and the RSP, reported as 24-h averages, were obtained once every 6 d from 9 separate monitoring stations. Four of the nine locations also provided sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) concentrations as 1-h averages throughout the period. The ranges of the various pollutants are listed in Table 5, together with the relevant Air Quality Objective (AQO) levels as stipulated by the Hong Kong EPD.

There were no appreciable differences in pollutant levels between the nine sites, suggesting fairly consistent air quality throughout Hong Kong. Two of the monitoring stations, Tai Po and Yuen Long, were situated more than 15 km from the city centre, outside the recruitment area for the personal monitoring study. Table 5 shows that all of the pollutants levels were below their respective AQOs for the entire study period. The EPD also produces an Air Pollution Index (API) based on the measurements of six air pollutants: NO_2, SO_2, ozone, carbon monoxide, TSP, and RSP for the three district types in Hong Kong. The API results are presented in Fig. 1 and show that the air quality could be classified as "moderate" for the entire study period. Figure 1 also shows the consistent nature of the air quality throughout the various districts of Hong Kong. These district measurements might suggest that the results from the personal monitoring study would not be influenced by the home or work locations of the recruits, but no attempt has been made to correlate these findings. In any case, variation in particulate levels, for example, can occur on a daily basis, potentially affecting indoor concentrations from outdoor air penetration.

SMOKING STATUS

Saliva cotinine levels were determined in order to verify that recruited subjects had correctly reported themselves as nonsmokers. Various threshold levels, above which subjects would be classified as smokers, have been suggested and include 10 ng mL^{-1} (Etzel 1990), 15 ng mL^{-1} (McNeill et al. 1987), 30 ng mL^{-1} (Lee 1987), and more recently 100 ng mL^{-1} (Sterling et al. 1996). In this study, 25 ng mL^{-1} (maximum of pre- and post-levels) was chosen as a suitable cut-off level, as used and described previously by these

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Table 5. Hong Kong EPD airborne pollutant data.

Monitoring site	District type	TSP[a] ($\mu g\ m^{-3}$)	RSP[b] ($\mu g\ m^{-3}$)	SO_2[c] ($\mu g\ m^{-3}$)	NO_2[c] ($\mu g\ m^{-3}$)
Kwun Tung	Industrial	107 - 202	88 - 106	0 - 162	8 - 220
Sha Tin	New development	54 - 147	31 - 89	0 - 131	3 - 173
Tai Po	New development	66 - 178	36 - 118	-	-
Yuen Long	New development	107 - 262	58 - 137	-	-
Sham Shui Po	Urban	84 - 203	51 - 117	-	-
Central/Western	Urban	93 - 196	48 - 110	3 - 128	16 - 164
Tsuen Wan	Industrial	82 - 194	45 - 106	-	-
Kwai Chung	Industrial	104 - 171	34 - 95	-	-
Mon Kok	Urban	119 - 259	60 - 124	4 - 189	15 - 267
Air Quality Objective[d]		260[e]	180[e]	800[f]	300[f]

[a] TSP reported as a 24-h average.
[b] RSP reported as a 24-h average.
[c] Reported as a 1-h average.
[d] As stipulated by the Hong Kong EPD.
[e] Not to be exceeded more than once per year.
[f] Not to be exceeded more than three times per year.

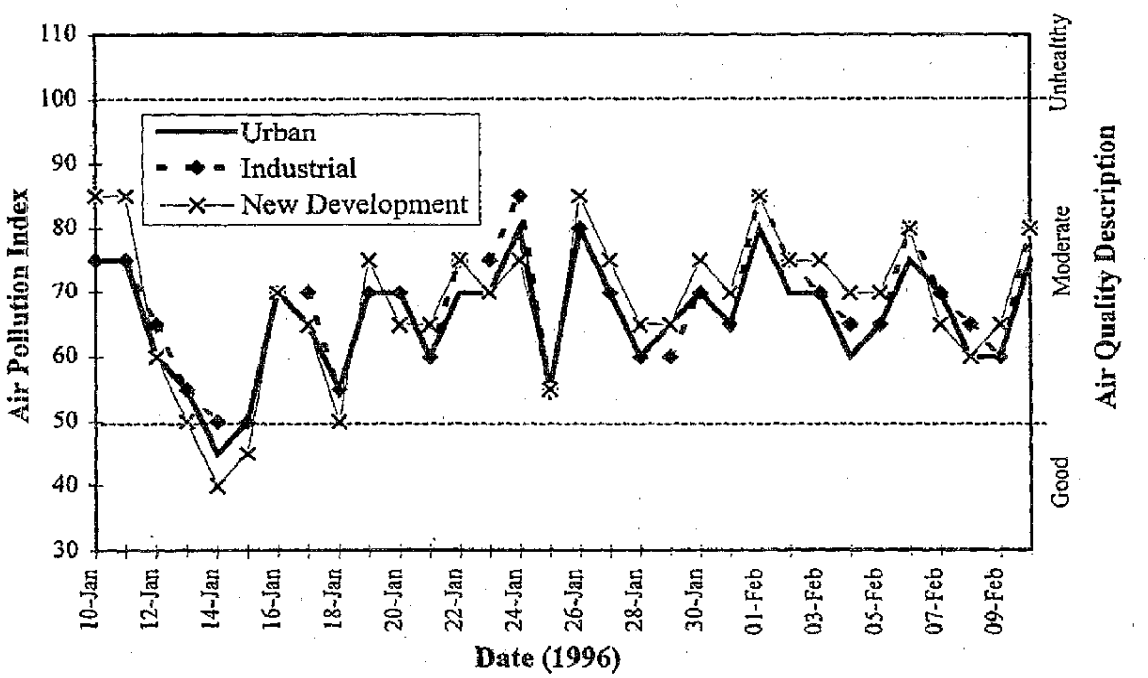

Fig. 1. Outdoor air quality (Hong Kong). Data obtained from the Hong Kong Environmental Protection Agency.

authors (Phillips et al. 1994). Using this threshold, 11 subjects with levels between 30.1 and 438 ng mL^{-1} were assumed to be smokers and were excluded from the study. Two subjects were excluded from the study after admitting to being smokers on the first visit questionnaire; however, their levels (0.5 and 2.6 ng mL^{-1}) suggest they either abstained from smoking for several days or misreported their smoking status.

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In this study, the subjects were required to confirm they had been nonsmokers for more than six months and no attempt was made to differentiate between "non" and "never" smokers. Various criteria can be used to assess the rate at which recruited subjects misreport their smoking status, including responses to questionnaires. Depending upon the criteria used, the rate at which subjects misclassified their nonsmoking status in this study ranged between 5.4% (11 from 205) and 6.3% (13 from 207). These misclassification rates are similar to the overall average rates (5.0% and 7.0%) observed in the European cities studied by these authors.

Etzel's review (1990) of the use of saliva cotinine for this purpose suggests that subjects with cotinine levels between 10 and 100 ng mL^{-1} may be classified as infrequent smokers, and had 10 ng mL^{-1} been selected as the cut-off level, a further four subjects would have been rejected. Delfino et al. (1993) rejected only 3 out of 251 subjects using a cut-off of 20 ng mL^{-1}, whereas Sterling et al. (1996) could have rejected 2 out of 25 had they used a similar threshold level instead of 100 ng mL^{-1}. In a study of cardiovascular risk factors in 5115 young adults (CARDIA), Wagenknecht et al. (1992) found a misclassification rate of 4.2% based upon a serum cotinine cut-off of 14 ng mL^{-1}. They classified nonsmokers as subjects having reported smoking less than five cigarettes per week for the previous three months. An exclusion rate of 4.2%, using a 15 ng mL^{-1} saliva discrimination level, was also found on a recent personal air monitoring study (Jenkins et al. 1996) of 1564 subjects in the United States. A discrimination level of 15 ng mL^{-1} was also chosen in a recent follow-up population study on smoking misclassification in southern Germany (Heller et al. 1998). In this German study, the proportion of self-reported nonsmokers with a cotinine level above 15 ng mL^{-1} was 3%.

RESULTS AND DISCUSSION

To assign a subject to a particular "Cell", procedures must be defined to classify the household and/or workplace as "smoking" or "nonsmoking". In a recent U.S. study, using a similar protocol to this study, Jenkins et al. (1996) reported data based on two separate procedures. Initially subjects were assigned to a Cell based upon their responses to the telephone screening questionnaire. Cell categorisations were subsequently refined by rejection of subjects whose diary observations did not correspond with their initial Cell assignments.

In this study, neither of the above procedures were utilised. Instead, Cells were categorised according to the answers provided on the first visit questionnaire. It was believed that responses to the screening questionnaire could not always be guaranteed due to the possible incorrect categorisation of Cells by telephonists working for the recruitment agencies. It was noted on the pump survey questionnaires that 68% of subjects admitted to incomplete recording of diary observations throughout the monitoring period. Thus, using diary observations to refine Cell categorisation was not considered.

Comparison of "markers" for estimating ETS concentrations

Table 6 lists the correlation and best fit line coefficients between various analytes measured in this study, after removal of data pairs where either analyte was below the LOQ. The correlations between SolPM/FPM and SolPM/3-EP are also depicted as scatter diagrams (Figs. 2 and 3), and the cumulative frequency distributions for particulates are presented in Fig. 4.

Examination of Table 6 shows a fairly good correlation between ETS particle estimates using SolPM and FPM methods ($R^2 = 0.80$) and a poor correlation ($R^2 = 0.24$) between SolPM and UVPM methods. Figure 2 shows that FPM estimates of ETS particles were considerably higher than SolPM for a large proportion of samples. This may suggest the presence of particles from combustion processes, for example, coal burning, not related to ETS. It has been suggested previously (Ogden et al. 1990) that SolPM methods are more specific to ETS particles than the use of UVPM and, to a lesser extent, FPM methods which are known to be sensitive to other combustion sources. Throughout this publication, ETS particle concentrations, corresponding cigarette equivalent (CE) calculations, and comparisons between subject groups and Cells have been based primarily upon SolPM determinations, although FPM values have been reported alongside for comparison.

An excellent correlation was evident between the vapour phase analytes nicotine and 3-EP ($R^2 = 0.97$), and fairly good correlations between both of these analytes and SolPM. There was an indication that 3-EP measurements correlated better with the particulate phase estimates than nicotine, possibly suggesting the applicability of 3-EP as an ETS particulate phase marker. However, the results presented here also suggest that FPM correlates better than SolPM with the

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Table 6. Correlation coefficients for ETS 'markers' using only data greater than the LOQ (Hong Kong).

"Y" data	vs	"X" data	Data pairs	R-squared	Gradient	Intercept
FPM		UVPM	260	0.777	0.538	-0.24
SolPM		UVPM	122	0.243	0.333	-0.59
SolPM		FPM	145	0.797	0.589	0.16
3-EP		Nicotine	77	0.968	0.191	0.36
FPM		Nicotine	102	0.875	4.752	8.52
SolPM		Nicotine	81	0.670	2.676	6.52
UVPM		Nicotine	85	0.012	0.639	16.57
SolPM		3-EP	73	0.785	14.906	0.20
FPM		3-EP	87	0.898	24.736	-0.77
Post-cotinine		Nicotine*	13	0.031	0.041	2.38
Post-cotinine		SolPM*	18	0.111	0.030	1.97
Post-cotinine		FPM*	55	0.070	0.014	1.62

* TWA concentrations used for working subjects (Cells 3 to 6) having results from both the "workplace" and "outside of the workplace" monitors greater than the LOQ.

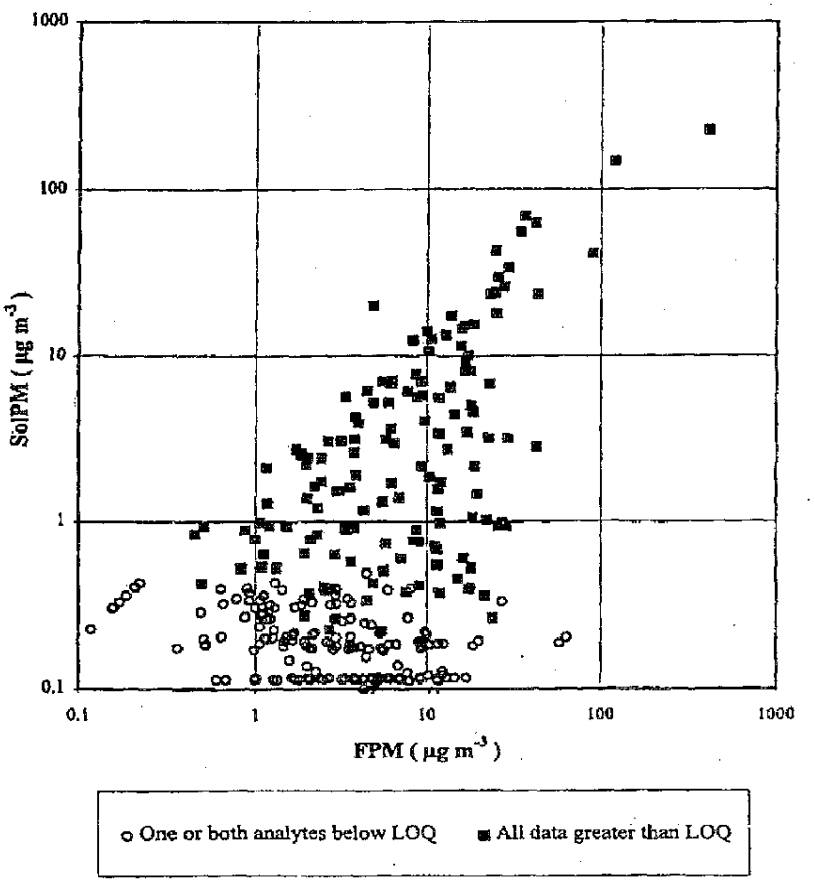

Fig. 2. Correlation of SolPM with FPM (Hong Kong).

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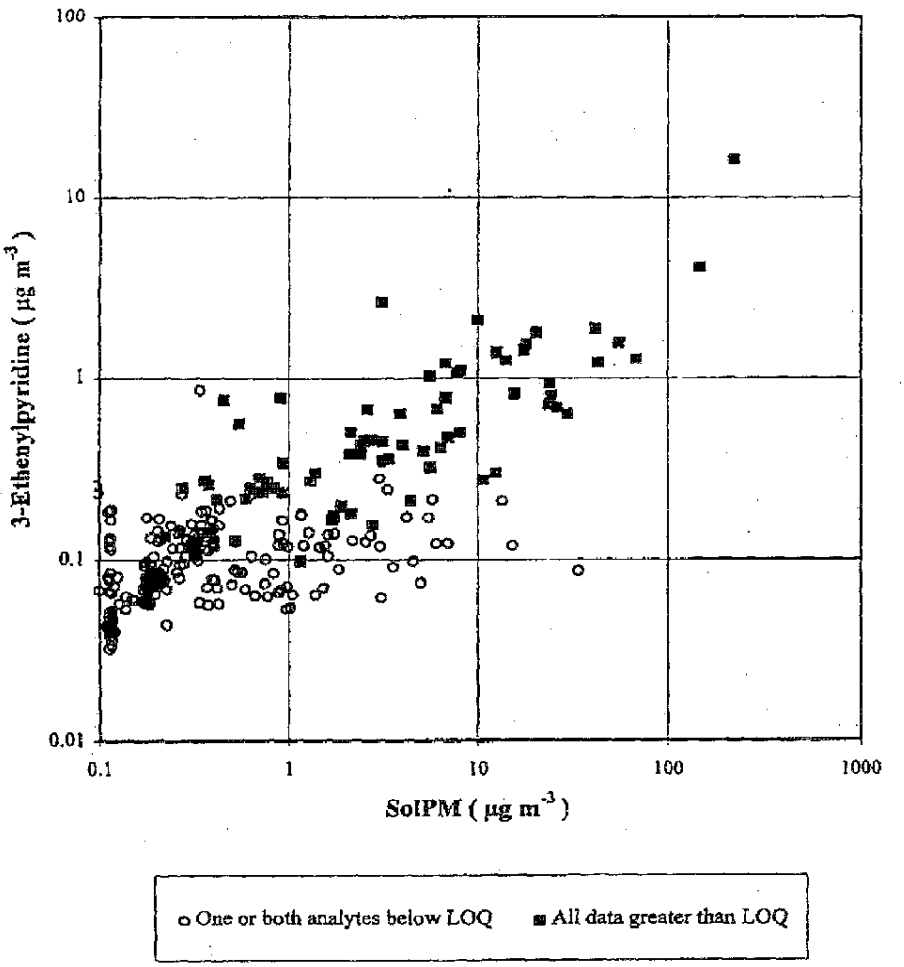

Fig. 3. Correlation of 3-EP with SolPM (Hong Kong).

vapour phase analytes, highlighting the difficulties in using any of the currently available methods as a single definitive marker for ETS exposure.

There were poor correlations for post-cotinine concentrations with both vapour and particulate phase ETS measurements. These poor correlations may be due to the large proportion of results being close to or below the LOQ, where acceptable assay reliability is at a minimum. These results reinforce previous findings that cotinine measurements, based on the current LOQ, do not provide a reliable marker for individual ETS exposure assessment.

Concentrations of ETS constituents to which Hong Kong subjects were exposed

In this publication, median values were primarily used for reporting RSP and ETS marker concentrations since the data generated were highly skewed. These summary statistics, together with geometric means, arithmetic means, 10th percentile (lower decile), and 90th percentile (upper decile) values were reported for each data set.

Particulate and vapour phase components measured for housewives were compared, by Ceil, with calculated time-weighted average (TWA) concentrations for

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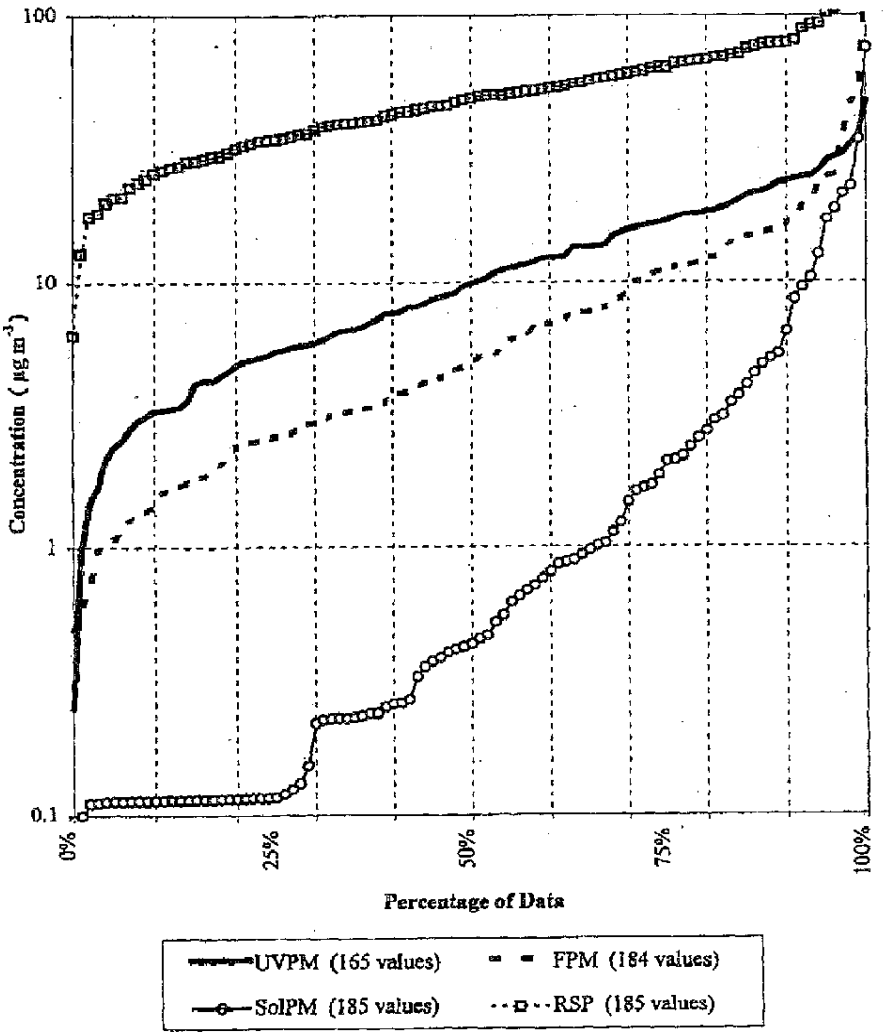

Fig. 4. Cumulative frequency distributions of 24-h TWA particulate matter concentrations (Hong Kong).

individual workers. These calculations were based on measured concentrations and the operational time over which the monitors were used inside and outside the workplace. These data are summarised in Tables 7 and 8. A cumulative frequency distribution for nicotine by Cell is shown in Fig. 5.

The significance of any concentration differences between Cells was examined using the Wilcoxon rank sum test. Prior to the application of this nonparametric test, Kruskal-Wallis nonparametric analysis of variance (ANOVA) was applied to the data in order to detect if there was an overall difference between the Cells. For both RSP and UVPM, the overall Kruskal-Wallis analysis was nonsignificant ($p>0.05$) and the Wilcoxon rank sum tests were not performed as there would have been the possibility of false positives. For all the other analytes investigated, the Kruskal-Wallis ANOVA provided evidence of a significant overall difference between Cells and subsequent pairwise comparisons of Cells were performed using the Wilcoxon rank sum test.

The median 24-h TWA RSP concentrations found in this study varied between 43 and 54 µg m^{-3}, with no significant differences ($p>0.05$) between any of the

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Table 7. Summary statistics for 24-h TWA particle concentrations for all subjects (Hong Kong).

Analyte ($\mu g\ m^{-3}$)	Subject group	n	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
RSP	Cell 1	35	23	77	49	44	45
	Cell 2	34	25	70	47	43	46
	Cell 3	19	35	99	66	56	53
	Cell 4	27	27	70	51	46	50
	Cell 5	29	26	103	60	54	54
	Cell 6	41	23	74	47	42	43
SolPM	Cell 1	35	0.11	0.74	0.99	0.20	0.12
	Cell 2	34	0.11	0.20	0.23	0.14	0.11
	Cell 3	19	0.44	30	12	3.5	2.6
	Cell 4	27	0.24	7.6	3.5	1.6	1.7
	Cell 5	29	0.25	18	5.4	2.2	2.1
	Cell 6	41	0.23	2.2	0.97	0.64	0.57
FPM	Cell 1	35	2.1	21	8.1	5.6	5.3
	Cell 2	34	1.4	12	6.5	4.2	3.9
	Cell 3	19	2.5	49	20	8.9	7.5
	Cell 4	27	1.5	17	8.5	6.0	7.6
	Cell 5	28	1.8	16	10	6.7	7.3
	Cell 6	41	1.1	11	5.7	3.5	3.2
UVPM	Cell 1	31	4.1	22	11	8.7	10
	Cell 2	33	3.3	19	10	7.6	8.6
	Cell 3	16	5.5	24	15	12	16
	Cell 4	22	3.0	32	15	11	13
	Cell 5	25	3.9	24	13	10	11
	Cell 6	38	2.9	20	10	7.4	6.8

Cell 1: smoking household; Cell 2: nonsmoking household; Cell 3: smoking household /smoking workplace; Cell 4: smoking household/nonsmoking workplace; Cell 5: nonsmoking household/smoking workplace; Cell 6: nonsmoking household/nonsmoking workplace. TWA exposure concentrations, determined for each subject from measured levels both inside and outside the workplace, were used to calculate the above statistical parameters for Cells 3 to 6.

Cells investigated. This would suggest that, in Hong Kong, tobacco smoke did not significantly contribute to RSP levels in indoor environments. High outdoor RSP levels may be expected to elevate indoor concentrations, and, as a result, could mask differences in personal exposure levels influenced by the smoking status of the environments. The RSP levels determined by personal monitoring in Hong Kong appear to be somewhat lower than the outdoor levels reported in Table 5, which showed an overall average of 82 $\mu g\ m^{-3}$. This difference may be due in part to air conditioning systems used indoors, and may also be a result of the different analytical methodologies used. RSP results reported by the Hong Kong EPD were based on particles less than 10 μm (PM_{10}), compared with $PM_{2.5}$ used for the personal monitoring study. The median TWA personal RSP levels measured in this study were similar overall to those determined by these authors in Paris (Phillips et al. 1998a), but were considerably lower than those found in either Barcelona or Turin (median levels between 51 and 100 $\mu g\ m^{-3}$). The median RSP levels in Hong Kong were up to three times higher than those found in the recent 16-city U.S. study (Jenkins et al. 1996) or the other European cities studied by these authors.

The highest median level for ETS particles (2.6 $\mu g\ m^{-3}$ for SolPM) was determined for subjects in Cell 3 (smoking household, smoking workplace), this concentration

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Table 8. Summary statistics for cotinine and 24-h TWA nicotine and 3-EP concentrations for all subjects (Hong Kong).

Analyte	Subject group	n	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
Nicotine (μg m^{-3})	Cell 1	31	0.04	0.51	0.26	0.12	0.07
	Cell 2	33	0.04	0.27	0.10	0.07	0.05
	Cell 3	18	0.12	7.0	3.2	0.74	0.44
	Cell 4	25	0.09	1.2	0.62	0.32	0.27
	Cell 5	22	0.10	0.66	0.32	0.25	0.24
	Cell 6	43	0.08	0.22	0.17	0.13	0.10
3-EP (μg m^{-3})	Cell 1	31	0.04	0.26	0.15	0.09	0.06
	Cell 2	33	0.04	0.18	0.09	0.07	0.05
	Cell 3	18	0.11	2.0	0.92	0.47	0.45
	Cell 4	25	0.09	0.59	0.29	0.21	0.19
	Cell 5	22	0.08	0.54	0.24	0.19	0.16
	Cell 6	43	0.08	0.23	0.13	0.11	0.10
Cotinine* (ng mL^{-1})	Cell 1	35	0.50	1.9	0.97	0.81	0.50
	Cell 2	35	0.50	1.2	0.68	0.60	0.50
	Cell 3	21	0.50	2.8	1.7	1.3	1.2
	Cell 4	29	0.50	2.1	1.2	1.1	1.1
	Cell 5	31	0.50	2.2	0.89	0.75	0.50
	Cell 6	43	0.50	0.93	0.63	0.59	0.50

Cell 1: smoking household; Cell 2: nonsmoking household; Cell 3: smoking household /smoking workplace; Cell 4: smoking household/nonsmoking workplace; Cell 5: nonsmoking household/smoking workplace; Cell 6: nonsmoking household/nonsmoking workplace.

* Values calculated from the average of pre- and post-monitoring saliva cotinine concentrations.

TWA exposure concentrations, determined for each subject from measured levels both inside and outside the workplace, were used to calculate the above vapour phase statistical parameters for Cells 3 to 6.

representing approximately 5% of measured RSP. The levels determined for this Cell were not significantly different ($P>0.05$) from those in Cells 4 or 5 (workers from either a smoking household or workplace) but were significantly higher ($P\leq 0.001$) than all other Cells. In all previous cities studied by these authors, subjects from Cell 3 were exposed to the highest levels of ETS particles, with medians varying from 3.0 μg m^{-3} in Stockholm to 35 μg m^{-3} in Barcelona. The median concentration reported here was the lowest found to date by these authors and was also approximately 30% lower than the equivalent Cell in the recent U.S. study (Jenkins et al. 1996).

Housewives, irrespective of the smoking status of their household, were exposed to significantly lower ($P\leq 0.05$) levels of ETS particles than any group of office workers in this study and median levels were below the LOQ. The median levels of ETS particles for office workers from smoking workplaces (Cells 3 and 5) were more than 10 times higher than that for housewives from smoking households (Cell 1). These results would suggest that the workplace, or the lifestyle of office workers, is a major contribution to overall ETS particle exposures. However, as discussed above, overall personal exposures to ETS particles for office workers from Cell 3 were the lowest reported to date.

The highest median nicotine concentration (0.44 μg m^{-3}) was again found for Cell 3, with measured levels significantly higher ($p\leq 0.01$) than all other Cells except Cell 4. Again, as with ETS particle concentrations, the lowest levels were measured for housewives from smoking and nonsmoking households (Cells 1 and 2) with no significant differences ($p>0.05$) between these two Cells. Overall the measured nicotine concentrations were low, with median levels for Cells 1, 2, and 6 all being below the LOQ. A slightly different pattern was evident for nicotine than for SolPM and significantly higher nicotine levels were measured for Cell 4 compared with Cell 6 and for Cell 3 compared with Cell 5. This would indicate that, for office

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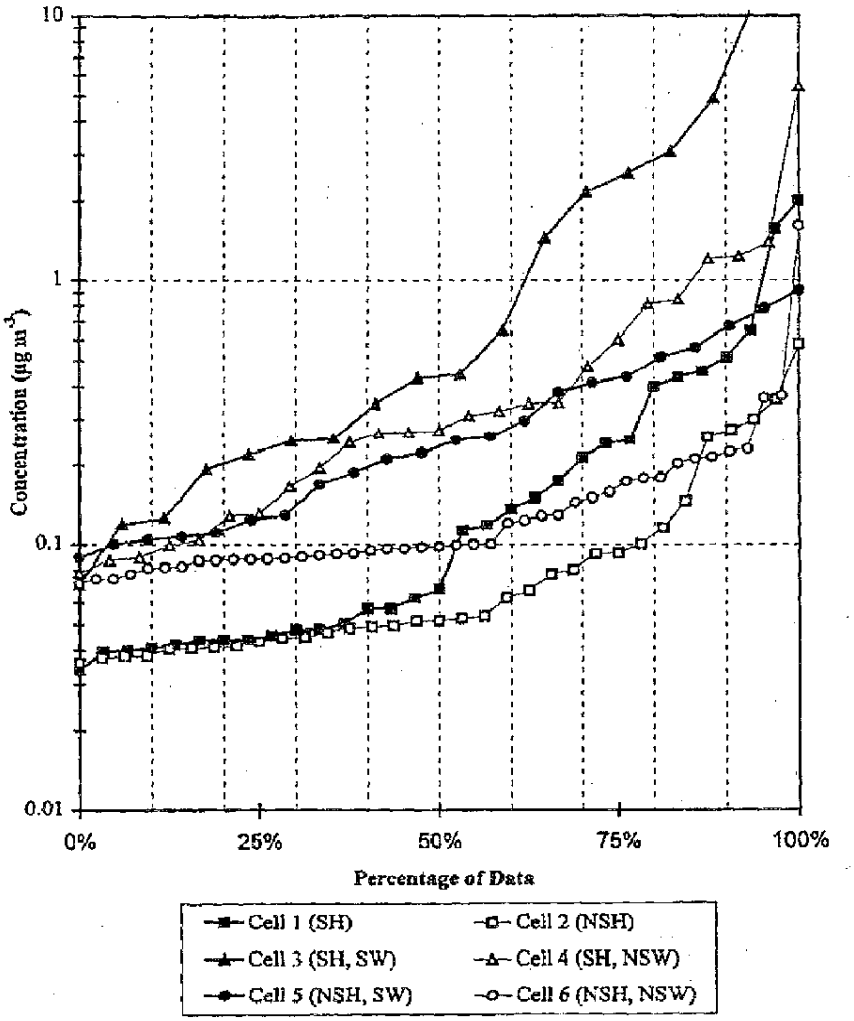

Fig. 5. Cumulative frequency distributions for nicotine by Cell (Hong Kong).

workers, the smoking status of the household is a significant factor in overall ETS exposure, with workers from smoking households exposed to significantly higher nicotine levels. The cumulative frequency distributions for nicotine by Cell (Fig. 5) show Cell 3 subjects were exposed to the most nicotine overall. In contrast, the smoking status of the household has no significant effect upon the ETS exposure levels for housewives in Hong Kong. Lee (1995), in a study of 400 married Japanese women, concluded that using 'marriage to a smoker' as a marker for ETS exposure was unreliable. The measurements obtained for this study support the Japanese findings. The reason for the differences between housewives and office workers in Hong Kong is unclear, but may be due to social or behavioural differences between the two groups. It is conceivable that smoking spouses, in South East Asian households, smoke mainly away from the family home.

For employed subjects living in smoking households and working in nonsmoking workplaces in Hong Kong (Cell 4), the median ETS particle level (SolPM) was nearly double that found for equivalent U.S. subjects. However, the median nicotine level for the same Cell was 40% lower in Hong Kong than in the U.S. For Cell 5 subjects (nonsmoking household, smoking workplace) in Hong Kong, the

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median ETS particle concentration was more than 12 times higher and the median nicotine level was approximately double that found for equivalent subjects in the U.S. study. These data may suggest a higher contribution from a smoking workplace to the overall ETS exposure of office workers in Hong Kong than in the U.S.

The 3-EP concentrations showed a similar trend to nicotine, although median levels were slightly lower and 90th percentile levels were up to 3 times lower than nicotine. The Wilcoxon rank sum test results for 3-EP data were also similar to those for nicotine, except that significant ($p \leq 0.05$) differences were detected between Cells 3 and 4 and between Cells 1 and 6. These data may suggest that 3-EP is an equivalent or better marker for vapour phase ETS than nicotine.

Saliva cotinine

Saliva cotinine concentrations, expressed as an average of pre- and post-monitoring levels, are reported by Cell in Table 8. The levels determined for subjects either working or living in a smoking environment (Cells 1, 3, 4, and 5) were significantly higher ($p \leq 0.05$) than those reported for subjects not usually exposed to smoking environments (Cells 2 and 6). The highest median concentrations (1.2 and 1.1 ng mL^{-1}) were recorded for Cells 3 and 4, working subjects who lived with smokers, with no significant difference ($p > 0.05$) between the two Cells. The levels found in Cells 3 and 4 were significantly higher ($p \leq 0.05$) than all other Cells, supporting the previous suggestions that working subjects were the most highly exposed and that living with a smoker was a major contributor to overall ETS exposure of working subjects. Cotinine was not intended to be used as a marker for ETS exposure in this study and a large majority of the levels found were close to, or below, the LOQ (1.0 ng mL^{-1}). However, statistical analysis of cotinine measurements showed significant differences between the various Cells investigated with similar precision to that found with either nicotine or SolPM measurements. Additionally, significant differences ($p \leq 0.05$) were detected between the saliva cotinine determinations for Cells 1 and 2, housewives from smoking and nonsmoking households, despite medians for both of these Cells being below the LOQ. These data appear to suggest that saliva cotinine can be used as a marker for overall ETS exposure of large groups. The reliability of cotinine measurements as an ETS marker at the individual level might be increased if the analytical LOQ was improved; however, dietary and metabolic effects remain confounders.

Exposures to RSP, ETS particles, and nicotine

The term "exposure" is often used when defining maximum allowable concentrations for hazardous compounds, and is normally determined by fixed site monitoring over standard time periods. In the context of this personal monitoring study, where concentrations cannot be directly related to a specific environment, "potential inhaled quantity" (PIQ) is used as a measure of overall exposure and was calculated as the product of the analyte concentration, the length of time subjected to such concentration and the breathing rate maintained throughout the period. A similar assumption was recently made by Ogden and Martin (1997), who noted that this provided "a more accurate accounting of total exposure among individuals as they engage in different activities in different microenvironments". Where PIQs are quoted in terms of CEs, these were calculated in relation to the mainstream particle (tar) and nicotine yields of typical cigarettes. Data regarding the yields of local cigarettes were not available and the values of 12 mg ETS particles and 1 mg nicotine were used. These values were calculated from the mean yields of the top six selling cigarette brand types in each of the eight European countries studied by these authors. In this publication, CEs are used solely for conceptual comparison of exposures between groups of nonsmokers. The authors understand and accept that mainstream smoke inhaled by smokers has a different chemical composition to ETS, which is composed mainly of side stream smoke and the exhaled portion from smokers. The factor used to relate exposure of nonsmokers to smokers and to predict potential health risks (Ogden and Martin 1997) was not applied.

Daily PIQs (μg), calculated for each subject group (Cell) over the 24-h monitoring period, are summarised in Table 9. The daily PIQ for each subject was calculated using the concentrations and sampling times determined from their individual monitors and the assumed "awake" breathing rates of 0.65 $m^3\ h^{-1}$ for females and 1.05 $m^3\ h^{-1}$ for males (Holcomb 1993). Median and upper decile PIQs were subsequently calculated for each Cell from these individually calculated daily exposures in order to represent "typical" and "highly exposed" subjects, respectively.

The RSP, nicotine, and ETS particle exposures, based on PIQs during the monitoring period, were also calculated using similar procedures according to subject

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Table 9. PIQs of RSP, ETS particles, and nicotine during the 24-h monitoring periods (Hong Kong).

Subject group	RSP (μg)	ETS particles SolPM (μg)	ETS particles FPM (μg)	Nicotine (μg)
	Median PIQs			
Cell 1	712	1.8	86	1.2
Cell 2	762	1.8	61	0.77
Cell 3	1241	45	166	9.9
Cell 4	902	29	117	5.5
Cell 5	992	37	154	5.6
Cell 6	859	11	65	2.3
	90th percentile PIQs			
Cell 1	1215	12	333	8.5
Cell 2	1146	5.0	196	4.5
Cell 3	2624	870	1124	168
Cell 4	1472	173	339	21
Cell 5	2108	282	376	10
Cell 6	1539	52	203	5.1

Cell 1: smoking household; Cell 2: nonsmoking household; Cell 3: smoking household/smoking workplace; Cell 4: smoking household /nonsmoking workplace; Cell 5: nonsmoking household/smoking workplace; Cell 6: nonsmoking household/nonsmoking workplace.
NB: PIQs were calculated using breathing rates of 0.65 $m^3 h^{-1}$ for females and 1.05 $m^3 h^{-1}$ for males.

Table 10. PIQs of RSP, ETS particles, and nicotine for males and females during the 24-h monitoring periods (Hong Kong).

Subject group*	RSP (μg)	ETS particles SolPM (μg)	ETS particles FPM (μg)	Nicotine (μg)
	Median PIQs			
Housewives	722	1.8	78	0.81
Female "workers"	752	27	91	3.4
Male "workers"	1234	25	136	3.8
	90th percentile PIQs			
Housewives	1208	7.1	227	7.4
Female "workers"	1372	224	253	18
Male "workers"	2306	241	412	26

* "Housewives" refers to subjects recruited for Cells 1 and 2 (single monitor).
"Workers" refers to subjects recruited for Cells 3 to 6 (dual monitor).
NB: A breathing rate of 0.65 $m^3 h^{-1}$ was assumed for females and 1.05 $m^3 h^{-1}$ for males.
The exposure time was that recorded on the monitors worn by each subject.

gender, and are reported in Table 10. Based upon the median PIQs, both male and female office workers in this study potentially inhaled at least four times the daily amounts of ETS particles (SolPM) and nicotine compared with housewives. These median PIQs also show that male workers had 64% higher daily exposures to RSP than females, a figure consistent with the 60% higher breathing rates assumed for males in the calculations. Male and female workers, however, had approximately equivalent daily PIQs of ETS particles and nicotine.

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Table 12. Estimated contribution of the workplace to annual exposures of RSP, ETS particles, and nicotine for all working subjects (Hong Kong).

		ETS particles		
Subject group	RSP	SolPM	FPM	Nicotine
Cell 3	21% (17%)	46% (38%)	24% (27%)	38% (34%)
Cell 4	15% (10%)	30% (29%)	13% (15%)	18% (18%)
Cell 5	20% (11%)	62% (33%)	27% (24%)	52% (24%)
Cell 6	21% (16%)	40% (27%)	23% (22%)	31% (16%)
All workers*	19% (14%)	44% (33%)	22% (22%)	33% (24%)

NB: Contributions reported as the mean (standard deviation) of percent annual work exposure for all subjects. Exposures were calculated assuming measured concentrations from each individual subject's monitors were maintained throughout the year and workers spend 35 h per week and 48 weeks per year at work.
Cell 3: smoking household/smoking workplace; Cell 4: smoking household /nonsmoking workplace; Cell 5: nonsmoking household/smoking workplace; Cell 6: nonsmoking household/nonsmoking workplace.
* All workers: Cells 3 to 6 combined.

their household. It was also apparent that workers living and working in nonsmoking environments (Cell 6) had considerably higher median PIQs of RSP, ETS particles, and nicotine than either group of housewives. The median and 90th percentile PIQs determined for workers from Cells 4 and 5 showed an inconsistent trend between the various analytes, possibly suggesting that smoking homes and workplaces had a similar contribution to the overall exposure of working subjects. The Wilcoxon rank sum test was also unable to differentiate between these two groups over the 24-h monitoring period.

Based upon median levels of ETS particles (SolPM) and nicotine, no group would be exposed annually to more than 3.3 CEs, and the least exposed, those subjects from entirely nonsmoking Cells (2 and 6), would be exposed to considerably less than 1 CE per year. The most highly exposed (90th percentile levels) nonsmokers in this study, who both worked and lived with smokers, would be exposed to between 11 (SolPM) and 50 (nicotine) CEs per year. Conversely, if they came from nonsmoking households/workplaces, they would be exposed to less than 1.5 CEs per year. For the majority of Cells investigated in Hong Kong, these exposures were the lowest reported to date by these authors.

It was also possible, by applying the same criteria used for the calculations in Table 11, to estimate the contribution of the workplace to overall annual exposure for each subject. A summary of these estimates, expressed as the mean percent contribution (standard deviation in parentheses) by Cell, is presented in Table 12. Overall, the workplace would appear to contribute between 33 and 44% of annual exposures to nicotine and ETS particles (SolPM), respectively.

Concentrations of RSP, ETS particles, nicotine, and 3-EP based on location

The concentrations of RSP, ETS particles, and nicotine to which working subjects were exposed, both inside and outside of the workplace, were assessed using data collected by the individual monitors. Individual monitor contributions were combined to provide an estimate of exposure concentrations in smoking (Table 13) and nonsmoking (Table 14) environments, both inside and outside the workplace. Comparison of saliva cotinine levels was not meaningful using this procedure and the data have been excluded from the tables.

In both smoking and nonsmoking environments, the median levels of RSP measured in the workplace ("work") were approximately 15% lower than those measured outside the workplace ("home"). It was also apparent that median RSP levels were approximately 30% higher in locations where smoking regularly took place. ETS particle (SolPM) and nicotine concentrations in the workplace were also higher than those measured outside the workplace, and concentrations in smoking locations were at least three times higher than the levels measured in nonsmoking locations.

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Table 11. Estimated annual PIQs for all subjects of RSP, ETS particles, and nicotine (Hong Kong).

	Annual PIQ (mg)						
		ETS particles			Cigarette equivalents		
Subject group	RSP	SolPM	FPM	Nicotine	SolPM	FPM	Nicotine
		Median PIQ					
Cell 1	258	0.66	30	0.39	0.05	2.5	0.39
Cell 2	265	0.65	22	0.29	0.05	1.8	0.29
Cell 3	439	19	56	3.3	1.6	4.7	3.3
Cell 4	367	7.0	46	2.7	0.58	3.9	2.7
Cell 5	393	9.8	51	1.4	0.82	4.3	1.4
Cell 6	352	3.5	22	0.79	0.29	1.8	0.79
All workers*	375	6.9	38	1.1	0.57	3.2	1.1
		90th percentile PIQ					
Cell 1	441	4.2	120	2.9	0.35	10	2.9
Cell 2	401	1.1	69	1.5	0.09	5.7	1.5
Cell 3	764	135	188	50	11	16	50
Cell 4	657	74	144	8.4	6.2	12	8.4
Cell 5	873	66	149	2.5	5.5	12	2.5
Cell 6	610	15	83	1.5	1.3	6.9	1.5
All workers*	726	67	152	5.7	5.6	13	5.7

Cell 1: smoking household; Cell 2: nonsmoking household; Cell 3: smoking household /smoking workplace; Cell 4: smoking household/nonsmoking workplace; Cell 5: nonsmoking household/smoking workplace; Cell 6: nonsmoking household /nonsmoking workplace.

* All workers: Cells 3 to 6 combined.

NB: A breathing rate of 0.65 $m^3 h^{-1}$ was assumed for females and 1.05 $m^3 h^{-1}$ for males. The exposure concentrations were those recorded on the monitors worn by each subject. Annual PIQs for Cells 1 and 2 subjects were calculated by extrapolation of their daily exposure levels to one year. PIQ calculations for working subjects were made by assuming a 35-h working week and 48-week working year with the remainder of the time spent at home.

To estimate annual PIQs, separate procedures were adopted for housewives compared with workers. Annual exposures in terms of PIQs for each housewife were calculated by assuming they were subjected to their measured concentrations for an entire year and that a breathing rate of 0.65 $m^3 h^{-1}$ was maintained at all times. For workers in Cells 3 to 6, annual PIQs were calculated for each subject from the data provided by the separate monitors worn in the workplace and away from the workplace. Male and female working subjects were assumed to have breathing rates of 1.05 $m^3 h^{-1}$ and 0.65 $m^3 h^{-1}$, respectively, at all times and to spend 35 h per week and 48 weeks per year in the workplace.

Annual PIQ calculations for all subjects assumed no variation in ETS marker concentrations throughout the year, including weekends, from those measured during the monitoring period. Median and upper decile PIQs by Cell, calculated from the estimated annual PIQs using the above assumptions, are reported in Table 11 together with PIQ estimates for ETS and nicotine in terms of CEs.

Using median ETS particle (SolPM) or nicotine PIQs, the estimates in Table 11 may be ranked in the order Cell 3 > Cell 5 = Cell 4 > Cell 6 > Cell 1 = Cell 2. With the exception of Cell 1 (housewives from smoking homes), this ranking was similar to those found by these authors in European cities. Annual PIQ estimates for Cell 1 in Hong Kong were ranked much lower than those found in previous cities, possibly highlighting cultural and behavioural differences between Asian and European housewives. Median PIQs of ETS particles and nicotine calculated for all workers (Cells 3 to 6) were between 2.8 and 11 times higher than those found for housewives, irrespective of the smoking status of

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Table 13. Summary analytical statistics for employed subjects in smoking environments (Hong Kong).

Analyte ($\mu g\ m^{-3}$)	Environment	n	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
RSP	Work*	48	17	112	66	49	51
	Home**	50	29	96	61	54	60
SolPM	Work*	48	0.33	47	18	3.8	5.2
	Home**	50	0.18	10	3.9	1.0	0.72
FPM	Work*	47	1.0	35	22	5.7	5.9
	Home**	50	2.0	19	10	7.3	9.1
UVPM	Work*	44	1.3	36	15	8.4	9.6
	Home**	40	3.5	30	16	12	15
Nicotine	Work*	40	0.10	4.0	3.3	0.56	0.52
	Home**	48	0.07	2.1	0.95	0.30	0.31
3-EP	Work*	40	0.10	1.6	1.1	0.40	0.35
	Home**	48	0.07	0.78	0.35	0.20	0.16

* Work – data from workplace monitor of subjects in Cells 3 and 5.
** Home – data from home monitor of subjects in Cells 3 and 4.

Table 14. Summary analytical statistics for employed subjects in nonsmoking environments (Hong Kong).

Analyte ($\mu g\ m^{-3}$)	Environment	n	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
RSP	Work*	68	15	72	42	34	38
	Home**	74	20	96	54	45	45
SolPM	Work*	68	0.30	5.6	2.0	0.87	0.51
	Home**	74	0.18	1.7	0.73	0.36	0.21
FPM	Work*	68	0.81	11	4.3	2.3	2.3
	Home**	74	0.74	18	7.6	3.7	3.6
UVPM	Work*	68	2.3	25	10	6.3	6.0
	Home**	66	2.2	27	11	7.6	7.3
Nicotine	Work*	69	0.10	0.32	0.28	0.17	0.13
	Home**	68	0.06	0.17	0.11	0.09	0.08
3-EP	Work*	69	0.10	0.35	0.21	0.16	0.14
	Home**	68	0.06	0.13	0.09	0.08	0.08

* Work – data from workplace monitor of subjects in Cells 4 and 6.
** Home – data from home monitor of subjects in Cells 5 and 6.

The median levels of ETS particles (SolPM) and nicotine (5.2 $\mu g\ m^{-3}$ and 0.52 $\mu g\ m^{-3}$, respectively) measured for subjects in smoking workplaces were at the lower end of concentrations found by these authors in European cities (SolPM range 0.59-37 $\mu g\ m^{-3}$; nicotine range 0.20-2.4 $\mu g\ m^{-3}$). However, these median levels were considerably higher than those reported by Jenkins et al. (1996) for comparable U.S. workplaces (SolPM 0.070 $\mu g\ m^{-3}$; nicotine 0.279 $\mu g\ m^{-3}$). Applying the same comparisons to the "away from work" results

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for subjects from smoking households showed that the median ETS particle level in Hong Kong (0.72 $\mu g\ m^{-3}$) was the lowest found to date by these authors (European range 1.1-21 $\mu g\ m^{-3}$). With the exception of Stockholm, the median nicotine level (0.31 $\mu g\ m^{-3}$) was also the lowest found to date (European range 0.15-0.97 $\mu g\ m^{-3}$). Jenkins' results for a comparable group (SolPM 1.25 $\mu g\ m^{-3}$; nicotine 0.79 $\mu g\ m^{-3}$) suggests higher ETS levels in smoking households in the U.S. than those in Hong Kong.

The home/work ratios for median ETS particle levels (Table 13) were almost identical for UVPM and FPM (1.56 vs 1.54), suggesting higher levels in the home than the workplace as determined by these non-specific methods. However, the same home/work ratio for SolPM was 0.14; this tobacco-specific marker indicating significantly higher ETS particle levels in the workplace compared to the home and elsewhere. These differences may be expected based upon contributions to UVPM and FPM from cooking and heating sources, particularly those used in communal buildings. The SolPM ratio again demonstrates that the home does not contribute significantly to ETS exposure in Hong Kong.

SUBJECTIVE COMPARISONS OF ETS EXPOSURE

As part of the last visit survey, subjects were asked a number of subjective questions regarding their exposure to ETS, both in general and during the 24-h monitoring period. Nearly half of the recruited subjects believed that outdoors was the single environment where they are generally exposed to the most ETS. This observation was somewhat different to those found in European cities where outdoor locations were not perceived as a major ETS source. It was possible that the good ventilation systems and different attitudes to smoking in Hong Kong resulted in lower indoor ETS exposure perceptions than those found in Europe. The low analytical results from the personal exposure study, in which the majority of the time was spent indoors, may also support these subjective observations. Restaurant or bar areas were selected by the largest number of subjects (26%) as the indoor location perceived to contribute most to overall ETS exposure, a similar observation to that found in all other cities studied by these authors.

CONCLUSIONS

Hong Kong was the ninth city investigated by these authors assessing exposures to RSP and ETS in a randomly selected sample of the nonsmoking population. The highest exposures to ETS particles and nicotine in this study were found for Cell 3 subjects, primarily office workers, who lived and worked in environments where smoking took place. Based upon median SolPM and nicotine concentrations, Cell 3 subjects in Hong Kong were exposed to the lowest levels encountered to date for comparable workers in other cities and would potentially inhale less than 3.5 CE per annum. Nicotine and ETS particle concentrations determined for subjects living in smoking households and working in nonsmoking workplaces (Cell 4) were not significantly different from the levels determined for those workers living in nonsmoking households and working in smoking workplaces (Cell 5). All groups of workers investigated in this study were exposed to significantly higher concentrations of ETS particles and nicotine than housewives. There was no significant difference between the levels of ETS particles and nicotine measured for housewives living with either smokers or nonsmokers, and neither group, based upon medians, would be exposed to more than 0.39 CE in a year.

Assessment of the data provided by the individual monitors worn by workers showed that levels of ETS particles and nicotine were highest within a smoking workplace. The median levels of nicotine were nearly double, and ETS particle levels more than 30 times higher in Hong Kong than those found in smoking workplaces in the U.S. (Jenkins et al. 1996). Median levels of ETS particles measured away from the workplace by subjects living with smokers were the lowest measured to date by these authors and were approximately 40% lower than those found by Jenkins et al. in the U.S. The workplaces investigated in Hong Kong were estimated to contribute between 33 and 44% of overall annual ETS exposure.

Personal RSP exposure levels were independent of the smoking status of the subjects' environments; there were no significant differences between any of the Cells investigated. RSP levels measured in Hong Kong were higher than the majority of those determined in European cities, with median levels falling between 43 and 53 $\mu g\ m^{-3}$, and were 2 to 3 times higher than those found in the U.S. However, the RSP levels found were somewhat lower than those measured outdoors, using a different analytical method, by the Hong Kong EPD.

Analysis of questionnaires showed that nearly half of the subjects perceived that outdoor locations were their major contributor to ETS exposure. These observations, together with the RSP and ETS results, suggest

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that a large number of indoor environments, including homes, utilise efficient air conditioning and filtration systems in Hong Kong.

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